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Indian Standard

TEXTILE FIBRES — TENSILE CHARACTERISTICS OF INDIVIDUAL FIBRES — METHODS FOR DETERMINATION

(First Revision)

भारतीय मानक

वस्त्रादि रेशे — अलग-अलग रेशों के तनन लक्षण — ज्ञात करने की पद्धति

(पहला पुनरीक्षण)

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Physical Methods of Test Sectional Committee, TDC 1

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards on 20 March 1989, after the draft finalized by the Physical Methods of Test Sectional Committee had been approved by the Textile Division Council.

This standard was first published in 1954 and included two methods for determining the mean single fibre strength and intrinsic strength (cotton). It has been revised with a view to include other tensile characteristics, namely, elongation (extension) and to cover testing of other textile fibres. The existing methods have also been updated on the basis of experience gained during their use and developments that have taken place after the publication of the standard. Assistance has been derived from ISO 5079-1977 'Textiles — Man-made fibres — Determination of breaking strength and elongation of individual fibres', and ASTM D 3822 'Test method for tensile properties of single textile fibres' issued by the International Organization for Standardization (ISO) and the American Society for Testing and Materials, respectively.

In reporting the results of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

TEXTILE FIBRES — TENSILE CHARACTERISTICS OF INDIVIDUAL FIBRES — METHODS FOR DETERMINATION

(First Revision)

1 SCOPE

1.1 This standard prescribes methods for determination of tensile characteristic of individual textile fibres.

1.1.1 The methods are applicable to all natural fibres and man-made fibres including crimped fibres provided that the available length of fibre enables a gauge length (effective distance between mountings) of 10 mm or 20 mm to be used.

2 GENERAL

2.1 The accuracy in the measurement of elongation is better from increased test length. Hence, wherever possible, longer gauge length should be used.

2.2 Determination of these fibre properties when carried out on different types of testing equipment, will not generally give identical results. To minimize the difference between results obtained on different types of testing equipment, this standard has been restricted to two types of testing equipment:

a) Equipment giving a constant rate of extension of the fibre, and

b) Equipment giving a constant rate of loading of the fibre.

2.2.1 Nevertheless, a difference up to 20 percent, depending on the rate of application of force and elongation, are to be expected between results for a given fibre when tested by the two types of equipment. For this reason, it is recommended that the comparative tests should only be carried out on one type of testing equipment, which should be agreed to by the interested parties.

3 REFERENCES

3.1 The following Indian Standards are necessary adjuncts to this standard :

IS No.	*Title*
IS 234 : 1973	Method for determination of linear density of textile fibres (gravimetric method) (*first revision*)
IS 1070 : 1977	Specification for water for general laboratory use (*second revision*)
IS 4807 : 1968	Method of testing viscose rayon staple fibres
IS 4952 : 1968	Methods of sampling cotton bales, slivers and rovings
IS 6359 : 1971	Methods for conditioning of textiles
IS 10014 (Part 2) : 1981	Methods of tests for man-made, staple fibres : Part 2 Determination of linear density

4 TERMINOLOGY

4.0 For the purpose of this standard, the following definitions shall apply.

4.1 Breaking Load

The maximum load supported by a specimen in a tensile test carried to rupture. It is usually expressed in gram force.

4.1.1 *Tenacity*

The breaking strength of a material under test in millinewton (mN) divided by linear density of the unstrained material in tex. It is expressed as mN/tex.

4.2 Breaking Strength

The maximum force supported by a specimen in a tensile test carried to rupture. It is commonly expressed in Newtons.

NOTE — Breaking strength in millinewtons (mN) = $g \times$ breaking load in grams where g is the acceleration due to gravity and its value is 981 cm/s².

4.3 Breaking Stress

The maximum stress developed in a specimen stretched to rupture. The force is usually related to the area of cross-section of the unstrained specimen. If the actual stress, defined in terms of the area of strained specimen is used, then its maximum value recorded at the time of rupture is called the actual breaking stress.

4.4 Constant Rate of Extension

A mechanism in which the specimen is elongated at a predetermined constant rate which is such that the average time-to-break will fall within the specified limits.

4.5 Constant Rate of Loading

A mechanism in which the specimen is subjected to a force that increases at a predetermined constant rate which is such that the average time-to-break will fall within the specified limits.

4.6 Elongation Percent

In a tensile test, the difference between the length of a stretched specimen and its initial length, usually expressed as a percentage of the latter.

4.7 Elongation at Break, Percent

In a tensile test, the difference between the length of a stretched specimen at breaking load and its initial length, usually expressed as a percentage of the latter.

4.8 Gauge Length

The length of the specimen under specified pre-tension, measured between two clamping points of the jaws of the holding clamps in their starting position at the beginning of the test. It is expressed in mm.

4.9 Modulus

The modulus is the ratio of stress to strain. It is expressed in mN/tex.

4.9.1 *Modulus, Initial*

The slope of the initial straight portion of a stress-strain curve. It is expressed in mN/tex.

4.9.2 *Modulus, Secant*

The ratio of change in stress to change in strain between the points of zero stress and breaking stress. It is expressed in mN/tex.

4.9.3 *Modulus, Tangent*

The ratio of change in stress to change in strain derived from the tangent to any point on a stress-strain curve. It is expressed in mN/tex.

4.10 Pre-Tension

The force per unit of linear density applied to a specimen at the beginning of the tensile test. It is expressed in mN/tex.

4.11 Time-to-Break

The time interval during which a specimen is under (a generally increasing) tension, to reach the breaking load.

NOTE — Time-to-break does not include the time required to remove slack from the specimen. On machines supplied with an autographic recorder, the time-to-break is indicated by the time lapsing after the pen registers the initial tension sustained by the specimen until the pen registers the maximum force.

4.12 Toughness

Toughness or specific work of rupture is the energy required to rupture a specimen of unit length and unit linear density. It is also equal to the work done to rupture unit mass of a specimen. It is expressed in millijoule/tex mm or mN mm/tex mm.

4.12.1 *Breaking Toughness*

It is obtained from the area under load elongation curve and is expressed in mN/tex.

5 SAMPLING

5.1 Natural Fibres

Cotton has maximum variation among natural fibres. Therefore, gross samples of other natural fibres, such as, wool, and jute, shall be carried out similar to that of cotton.

5.1.1 The gross sample shall be spread out evenly on a level ground in the form of either a square with each side slightly greater than 1 m or in the case of larger sample, a rectangle with the shorter side slightly greater than 1 m and the longer side slightly greater than 2 m. Over this, a metallic framework of size (1 m × 1 m) with 25 sub-square or (1 m × 2 m) with 50 sub-squares as the case may be, shall be placed ; from each of these sub-squares, one bunch or more of fibres shall be pulled out at random, taking care (a) not to exercise any bias in favour of or against any particular place within a sub-square, and (b) that the fibres drawn from each sub-square weigh about the same amount (about 4 g in the first case and about 2 g in the second case). The total quantity of about 100 g thus drawn shall constitute the reduced sample.

5.1.2 The reduced sample shall be divided into 25 or 50 approximately equal groups. From different portions of each of these groups, small tufts or fibres shall be extracted at random taking care that the fibres drawn are nearly equal in mass and the total mass of the fibres thus drawn is not less than 200 mg. This shall constitute the test sample.

5.1.3 For sampling of fibres, reference may be made to IS 4952 : 1968.

5.2 Man-Made Fibres

Test sample for man-made fibres shall be prepared as given in IS 4807 : 1968.

6 PREPARATION OF TEST SPECIMEN

6.1 Cotton and Other Natural Fibres

6.1.1 The test sample shall be cleaned and the fibres drawn between the forefinger and the thumb of one hand and those of the other. The fibres shall then be made into sliver which shall be drawn and doubled several times by hand.

6.1.2 A tuft of fibres taken from any end portion of the sliver shall constitute the test specimen for the purpose of mean individual fibre strength and elongation.

6.2 Man-Made Fibres

The procedure given in IS 4807 : 1968 shall be followed.

7 CONDITIONING OF TEST SPECIMEN

7.1 The test specimen shall be conditioned to moisture equilibrium from the dry side in the standard atmosphere at 65 ± 2 percent RH and 27 ± 2°C temperature in accordance with IS 6359 : 1971.

7.2 When a test specimen has been exposed to the standard atmosphere at least for 24 h in such a way as to expose, as far as possible, all portions of the test specimen to the standard atmosphere, it shall be deemed to have reached moisture equilibrium.

8 APPARATUS AND REAGENTS

8.1 A tensile machine with suitable clamps for gripping the test specimen at a gauge length of 10 or 20 mm, means for stretching the fibre to rupture and a method of indicating the force applied to the test specimen and the corresponding elongation. The permissible error of the indicated breaking strength shall not exceed 1 percent of the mean breaking strength of the fibres and the error of the indicated elongation at the breaking strength shall not exceed 0·1 mm. The error of gauge length shall not exceed 0·2 mm. Tensile testing machine of the type described in **8.1.2** and designed so as to avoid any jerk in the early stages of application of force may also be used.

8.1.1 *Constant Rate of Extension Machine*

The machine shall be capable of applying a constant rate of extension to the fibres such that after the first 2 s of the test, the rate of increase in the distance between the clamps does not differ by more than 5 percent from the average rate of increase over the whole period of test. The machine shall include facilities for producing different constant rates of extension in order to break the test specimen in an average time-to-break of 20 ± 3 s.

8.1.2 *Constant Rate of Loading Machine*

The machine shall be capable of applying force at a constant rate such that after the first 5 s of the test, the average rate of increase of force in any 2 s interval does not differ by more than 25 percent from the average rate of increase of force over the whole period of test. The machine shall include facilities for applying force at different constant rates in order to break the test specimens in an average time-to-break of 20 ± 3 s.

8.2 Clamps

There are flat jaws for gripping the fibre specimens and are designed to minimize slippage during the test.

8.3 Tabs

These are of thin plastic or other material for use with cementing techniques.

8.4 Means for enabling individual fibres to be placed without damage, between clamps of the instrument (*see* Annex A).

8.5 Cement or Adhesive

The adhesive must bind the tabs to the fibres without effecting an appreciable solution of the latter or any change in the moisture content of the specimen.

8.6 Distilled Water (*see* IS 1070 : 1977), at a temperature of 27 ± 2°C, to which a non-ionic wetting agent has been added, to give a concentration of about 0·1 percent.

8.7 Auxiliary Equipment

The testing machine may be equipped with auxiliary equipment to permit the automatic recording of data or the calculation of any required tensile property. The auxiliary equipment must be capable of recording data and performing calculations in a manner consistent with the definitions and instructions for calculations as described in this method.

8.8 Jig

This is to aid in accurately mounting the test specimens on tabs at the specified gauge length.

9 PROCEDURE

9.1 Condition the test specimen in the standard atmospheric conditions (*see* **7.1**).

9.2 Set the machine to give the required duration of test between the limits specified in **8.1.1** and **8.1.2**.

9.3 Prepare and mount an individual fibre in the clamps of the testing machine (*see* Annex A). Ensure that the fibre lies along the axis of elongation of the machine. Start the tensile testing machine and associated auxiliary equipment, extending the fibre specimen to break.

9.3.1 *Slack Mounting*

Mount the fibres individually slightly slack either directly between suitable clamps or on tabs.

9.3.2 *Pre-Tensioned Mounting*

Mount the fibres individually between suitable jaws and apply a tension of 5·0 ± 0·5 mN/tex for the dry test and 2·5 ± 0·3 mN/tex for the wet test, calculated from the mean linear density of the fibre.

NOTE — A higher pre-tension to remove crimp can be applied subject to the agreement between the concerned parties.

9.4 If the fibre specimen is mounted on tabs before being placed in the testing machine, the distance between tabs defines the nominal gauge length. The mounting of fibre specimens on tabs will be facilitated by the use of an appropriate jig.

9.4.1 When tabs are used, cut the tab across so that the fibre is free. Set the traversing jaw in motion and extend the test specimen to the point of rupture.

9.5 Unless, otherwise agreed by the interested parties test at least 50 specimens. Note jaw breaks, that is, breaks in which either of the broken ends is not visible and exclude the result obtained on such test specimens. The mean breaking load is the mean value of the breaking loads of all the fibres taken. The mean elongation (extension) at break is the mean value of the elongation (extension) at break of all test specimens. For determination of tenacity, the mean linear density of the test specimen shall be calculated as prescribed in IS 234 : 1973 and IS 10014 (Part II) : 1981 for natural and man-made fibres, respectively.

NOTE — As the coefficient of variation percent for the individual fibre tenacity is very high for natural fibres, more number of tests of specimens are advisable for a desirable degree of accuracy. If the confidence limits for 50 tests do not differ by more than ± 4 percent from the mean, then this value is taken as the mean of the lot. Otherwise, the number of tests shall be increased until the confidence limits are brought within ± 4 percent of the mean breaking load (For better significance of test results of natural fibres, at least 300 specimens may be taken and tested).

9.6 Wet Specimens

Determine the properties of wet fibres on specimens immersed in a 0·1 percent aqueous solution of a non-ionic wetting agent. Allow sufficient wetting-out time before testing to produce the maximum change in breaking load and elongation at break as indicated by no further change with longer periods of immersion.

10 EXPRESSION OF RESULTS

10.1 Calculate the mean breaking strength of the fibres tested and express the result in mN.

10.2 Compute the mean tenacity of the fibres as indicated in **4.1.1** and express the result in mN/tex.

10.3 Calculate the mean elongation at break of the fibres and the mean elongation at break as a percentage of the gauge length (*see* Annex B).

10.4 Calculate the coefficient of variation (percent) of the breaking strength and of the elongation at break.

10.5 In addition, if necessary, calculate any other required, tensile properties, namely, tenacity, modulus and breaking toughness, etc., (*see* Annex C).

11 TEST REPORT

11.1 The test report shall include the following:

a) Type of material tested;
b) Number of fibres tested;
c) Method followed : The method of mounting the fibres and the type of mounting, that is pretensioned or on support tab;
d) Gauge length used;
e) Mean tenacity of the fibres in mN/tex;
f) Mean elongation at break, in percent;
g) Coefficient of variation of the breaking strength and elongation at break; and
h) Result of any other tensile properties required.

ANNEX A

(*Clauses* 8.4 *and* 9.3)

MOUNTING OF TEST SPECIMEN

A-1 It must be emphasized that great care should be taken to ensure that the fibre is not damaged, for example, the length of the fibre under test must not be held with tweezers.

A-2 Mount a test specimen in the jaws of the clamps, removing slack without stretching the specimen. The specimen must be straight within the jaws and extreme care must be taken to ensure that the fibre specimen lies on the line of action between the force-measuring device and the point where the fibre leaves the moving jaw face. Any misalignment that tends to produce transverse motion of the clamps and jaws will introduce errors in measurements of elongation and may contribute to premature fibre failure.

NOTES

1 For a slack mounted fibre, a tab may be used. A rectangular hole whose length is equal to the gauge length is cut in the tab and the fibre is mounted across the hole by means of a suitable adhesive. It is essential that the adhesive should not spread over the length of the fibres under test and both the tabs and the adhesive must be water-proof.

2 For pre-tensioned fibres, suitable fibre clips must be attached to the testing machine. These can also be used for slack mounting, if desired.

ANNEX B

(*Clause* 10.3)

MEASUREMENT OF ELONGATION

B-1 In measuring breaking elongation, particularly of crimped fibres, difficulty lies in deciding the starting point of test.

B-1.1 The initial portion of the curve is rarely linear. This part of the curve represents the fibre bending in the grips, or the removal of the crimp, or a combination of these.

B-1.2 For this reason, in particular, where at the start of the force, elongation curve is very rounded, it may be useful to determine the theoretical start of elongation be extrapolation to zero force, from the straight portion of the force-elongation curve adjacent to the initial portion of the curve.

B-2 SLACK MOUNTING

From the force elongation curve, and taking into account of the gauge length used (10 mm or 20 mm), determine the length between the jaws of each test specimen, under a pre-tension 5·0 ± 0·5 mN/tex or 2·5 ± 0·3 mN/tex (*see* **9.3.2**). Use this length to calculate the percentage elongation at break of the fibre.

B-3 PRE-TENSION MOUNTING

The effective length of each test specimen between the jaws being equal to the gauge length, the percentage elongation at break of the fibre can be calculated directly from this gauge length.

ANNEX C

(*Clause* 10.5)

CALCULATIONS

C-1 EFFECTIVE SPECIMEN LENGTH

C-1.1 Calculate the effective specimen length by drawing a line *AB* tangent to the initial straight-line section of the load-elongation curve and extrapolate it to intersect the zero load axis at *I* (*see* Fig. 1). The correction (or addition) to specimem length in mm is given by the intercept *OI*. The effective specimen length (mm) is the initial distance between the clamps (the 'nominal specimen length') plus the correction (or additional specimen length) corresponding to *OI*.

C-1.2 When the load-elongation curve of a crimped specimen does not have an initial straight-line section below the yield point, draw a line tangent to the curve at the point of inflection below the yield point as an approximation of the initial modulus and report this fact.

C-2 ELONGATION AT BREAK

C-2.1 Mark a point *E*, on the zero load axis corresponding to the maximum load. Determine the elongation of the specimen in mm, corresponding to the length *IE*. Calculate the elongation at break as a percentage of the corrected effective specimen length using the equation:

$$\text{Elongation at break, percent} = 100 \times \frac{IE}{El_{sp}}$$

where

IE = specimen elongation (mm), and

El_{sp} = calculated effective specimen length = Nominal specimen length + additional specimen length (*OI*)

C-3 MODULUS, INITIAL

C-3.1 Initial modulus is a measure of resistance of the fibre to extension at loads below the yield point. For calculating initial modulus, calculate the tenacity in mN/tex corresponding to any convenient point *P* on the line *AB* by drawing a line *PC* perpendicular to the zero load axis. Calculate the fractional elongation (E_f) corresponding to *IC*, that is, the ratio of *IC* to the effective specimen length. Then calculate the initial modulus as follows:

$$\text{Modulus, initial} = \frac{\text{Tenacity (} PC/\text{tex)}}{E_f}$$

where

PC = load indicated by distance *PC* in Fig. 1, and

E_f = fractional elongtion corresponing to distance *IC*.

C-4 MODULUS, SECANT

The secant modulus is also used to estimate the resistance to imposed strain.

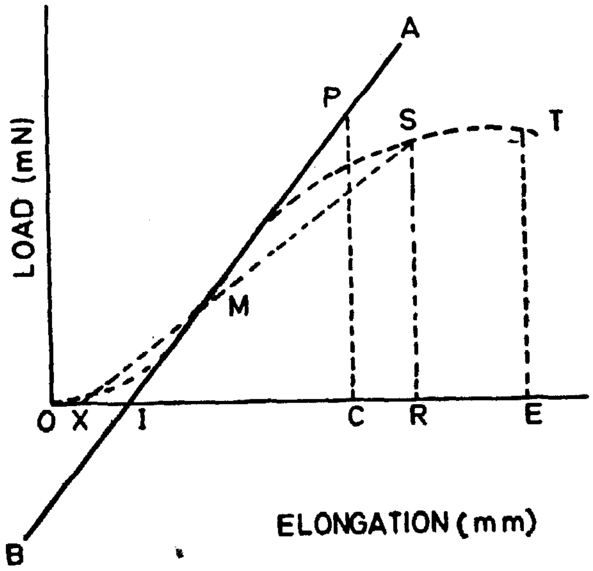
Draw a line between any two specified points, for example, *S* and *M*, on the load-elongation curve. Extrapolate the line to intersect the zero load axis at the point *X*. Drop a perpendicular from the point *S* to intersect the zero load axis at point *R*.

$$\text{Modulus, Secant} = \frac{\text{Tenacity (} SR/\text{tex)}}{E_f}$$

where

SR = load indicated by distance *SR* in Fig. 1, and

E_f = fractional elongation corresponding to distance *RX*.



AB - TANGENT TO CURVE OT

FIG. 1 A TYPICAL LOAD-ELONGATION CURVE (OT) OF INDIVIDUAL TEXTILE FIBRE

C-5 MODULUS, TANGENT

The tangent modulus may be used to differentiate between the probable performance of fibres in processing and end-use performance. Draw a line tangent to the load-elongation curve at the desired point on the curve which has been specified either in terms of stress or the elongation at the point. Select the points on the tangent line and calculate the slope of the line as described in **C-4**.

C-6 BREAKING TOUGHNESS

It is the energy per unit mass required to rupture the specimen. It is the integral of the nominal stress-strain curve and is calculated by dividing the work of rupture by the mass of the specimen under test.

Breaking toughness is calculated from the area under the load-elongation curve expressed as mN/tex (mNmm/tex mm).

Breaking toughness $= V/T$

where

T = linear density, tex; and

V = work done in extending the fibre, mN (mN mm/mm), that is $\left(\frac{A \times S \times R}{G \times W \times L}\right)$

where

A = area under load-elongation curve (mm^2),

S = full-scale load (mN),

R = crosshead speed (mm/min),

G = effective specimen length (corrected) (mm),

W = chart width (mm), and

L = chart speed (mm/min).

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